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Effects of an Acute Boxing Session on Muscle Activity in Persons with Parkinson's Disease

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Abstract

Purpose: This study assessed the acute effects of a boxing session on upper extremity muscle activity in people with Parkinson's Disease (PD).

Materials and Methods: Electromyography was used to assess upper extremity muscle activity in ten people with PD, fourteen healthy older adults, and twelve healthy younger adults during elbow flexion and extension at fast and self-paced movement before and after an acute boxing session.

Results: Results showed a significant difference in peak to offset time in the triceps brachii during fast movement (F(1)=8.181, p=0.009) and both peak amplitude (F(1)=4.587, p=0.042) in the triceps brachii and peak to offset time (F(1)=4.256, p=0.018) in the biceps brachii during self-paced movement from before to after the boxing session for all three groups. No differences between groups were revealed.

Conclusions: Triceps brachii muscle activity improved after an acute session of boxing, regardless of age or disease. Thus, people with PD may show similar benefits from boxing as healthy populations. Additional research should be conducted to further determine the efficacy of long-term boxing programs for people with PD, as well as how changes in triceps brachii muscle activity relate to functional outcomes.

Key Words: Parkinson's disease • Electromyography • Muscles • Boxing • Neurological rehabilitation • Exercise

Introduction

Parkinson's Disease (PD) is a chronic neurodegenerative disorder affecting roughly one million Americans [1] and between 100 and 200 per 100,000 persons worldwide [2]. The loss of dopamine-producing neurons in the pars compacta of the substantia nigra leads to PD and worsening symptoms. People with PD are affected primarily by motor symptoms such as bradykinesia, resting tremors, and rigidity. Parkinson's disease is treated through dopamine-promoting medication, surgical deep brain stimulation, and complementary therapies.

Research has shown that exercise and physical activity can benefit people with PD and combat symptoms not alleviated by medicine or surgery [3]. Current evidence-based physical activities that benefit people with PD include treadmill walking [4-6], tai chi [7-9], visual [10], auditory [10,11] and haptic [10] cued gait training, gait perturbation training [12], and cycling [13]. These physical activity modalities have been shown to ameliorate the severity of common motor symptoms in people with PD such as balance and mobility impairments. Another physical activity modality, adaptive boxing, may prove to be a motivating and effective alternative therapy for people with PD.

King and Horak [14] suggested physical activity that incorporates movements specifically targeting anticipatory postural adjustments, postural corrections, fast arm and foot motions, backward walking, timing, and sequencing actions are most beneficial for people with PD. The few studies on the use of boxing as an alternative therapeutic tool in people with PD have primarily focused on behavioral and well-being outcomes [15,16]. Preliminary qualitative work indicates people with PD who regularly participate in vigorous-intensity exercise, including adaptive boxing, perceive benefits in social connectedness, purpose, determination, and confidence [17]. Also, people with PD want and enjoy variety in their exercise programming [18]. This variety might be supplied through adaptive boxing. Regardless, there remains a need to better understand the underlying changes in muscle activity after boxing for people with PD to better determine the efficacy of boxing as an alternative therapeutic tool.

The purpose of this study was to determine the effects of an acute boxing session on upper extremity muscle activity in people with PD. Electromyography (EMG) was used to measure muscle activity before and after one session of boxing training in people with PD. EMG was also collected from Healthy Older Adults (HOAs) and Healthy Young Adults (HYAs) to determine the contribution of potential aging effects to changes in muscle activity. We hypothesized that an acute session of boxing would improve muscle timing and amplitude of the biceps brachii and triceps brachii muscles in people with PD and that this improvement would be specific to training, not aging.

Materials and Methods

This study was conducted in accordance with the principles set forth in the Helsinki Declaration. The Institutional Review Board of Iowa State University provided approval for the procedures of this study before the experiment was started. The Board was chaired by Kerry Agnitch, the protocol number was 17-613, and the approval date was January 23, 2018. All participants provided written informed consent for participation in this study and publication of data obtained by the study.

Participant demographics

Data were collected from 36 participants, including 10 people diagnosed with PD [mean age=69.7 ± 5.2; female (4), male (6), 12 healthy age- and sex-matched younger adults mean age=22.8 ± 2.9; female (5), male (7), and 14 healthy sex-matched older adults [mean age=65.0 ± 5.7; female (6), male (8).

The inclusion criteria for healthy older and young adult participants were:

1. between the ages of 18 and 85;
2. had no neurological impairment or disease, and
3. could complete a 45-minute boxing training session.

The inclusion criteria for participants with PD were:

1. clinical diagnosis of PD using the UK PDS Brain Bank Criteria [19];
2. between the ages of 40 and 85;
3. previous or current participation in the boxing outreach program, and
4. had a stable regimen of antiparkinsonian medication for the 30 days before study participation.

Exclusion criteria for all participants included a Mini-Mental State Examination score of less than 24 [20]. Demographic and disease

Table 1. Participant demographics.

Participant	Age	Gender	Handedness	Ethnicity	Education (years)	MAS	Disease Duration (years)	Boxing Duration (mo.)
PD_01	73	M	R	W	23	L	11	14
PD_02	62	M	R	Asian	24	L	2	13
PD_03	68	M	R	W	17.5	NA	1	7
PD_04	65	F	R	W	16	L	4	6
PD_05	65	F	R	W	18	R	0.25	3
PD_06	75	F	R	W	16	L	10	24
PD_07	78	M	R	W	24	NA	2	18
PD_08	74	M	R	W	20	R	3	18
PD_09	67	M	R	W	16	L	6	36
PD_10	70	F	R	W	16	L	16	36
HYA_01	22	M	R	W	16	NA	NA	NA
HYA_02	21	F	R	W	16	NA	NA	NA
HYA_03	22	F	R	W	16	NA	NA	NA
HYA_04	21	M	R	W	16	NA	NA	NA
HYA_05	22	F	R	W	16	NA	NA	NA
HYA_06	24	M	R	W	18	NA	NA	NA
HYA_07	27	F	L	Asian	22	NA	NA	NA
HYA_08	20	F	R	W	14	NA	NA	NA
HYA_09	21	M	R	W	15	NA	NA	NA
HYA_10	21	M	R	W	16	NA	NA	NA
HYA_11	30	M	L	W	16	NA	NA	NA
HYA_12	23	M	R	W	17	NA	NA	NA
HOA_01	71	F	R	W	18	NA	NA	NA
HOA_02	52	F	R	Asian	20	NA	NA	NA
HOA_03	64	F	R	W	16	NA	NA	NA
HOA_04	57	F	R	W	18	NA	NA	NA
HOA_05	65	F	R	W	16	NA	NA	NA
HOA_06	67	M	R	W	19	NA	NA	NA
HOA_07	69	M	R	W	19.5	NA	NA	NA
HOA_08	64	M	R	W	16	NA	NA	NA
HOA_09	65	M	R	W	14	NA	NA	NA
HOA_10	65	M	R	W	16	NA	NA	NA
HOA_11	72	F	R	W	22	NA	NA	NA
HOA_12	59	M	L	W	24	NA	NA	NA
HOA_13	70	M	R	W	18	NA	NA	NA
HOA_14	70	M	R	W	20	NA	NA	NA

mo: months, MAS: Most Affected Side, M: Male, F: Female, R: Right, L: Left, W: Caucasian, NA: Not Applicable, PD: Person with Parkinson's Disease, HYA: Healthy Young Adult, HOA: Healthy Older Adult

information was collected, and the length of participation time in the boxing outreach program was also recorded for all participants with PD.This information is shown in table 1. Participants with PD were on medication for the duration of the study.

Intervention overview

Participants were asked to complete a single, acute session of boxing with data collections before and after the session. The boxing session was led by a USA Boxing certified boxing coach. Each session included a brief warm-up for the upper body using lightweight dumbbells followed by agility and footwork drills. Next, participants performed shadow boxing and individualized pad work. Finally, participants engaged in a cool-down portion that involved static stretching of major muscle groups. The boxing session was approximately 45 minutes.

Pre/post-testing

Data collection was completed within 30 minutes before the boxing session and immediately following the boxing session. For both collections, Electromyography (EMG) was collected from surface electrodes placed on the biceps brachii and the triceps brachii of both arms. The participant was asked to perform flexion and extension at the elbow joint in the supinated position at a self-selected pace and as fast as possible. Participants were instructed to perform flexion and extension through the full range of motion. Twenty movements were collected per condition, per arm. Self-paced and fast movements per arm were randomized among participants, but an order of collection was the same from pre to post collection for each participant.

EMG data processing

EMG (Delsys Trigno) was recorded using The Motion Monitor™ software and sampled at 2000 Hz. A low pass filter at 500 Hz, a high pass filter at 1 Hz, and a notch filter at 60 Hz were applied. The raw signal was DC-corrected, full-wave rectified and smoothed using a root-mean-square envelope of 50 ms. The EMG signal was manually inspected for artifacts which resulted in a total of 2,386 flexion and extension trials available for statistical analysis. EMG outcome measures included peak amplitude, the area under the curve using the trapezoidal rule, time from burst onset to peak amplitude, and time from peak amplitude to burst offset. EMG outcome measures were obtained from the biceps brachii and the triceps brachii in the left and right upper extremities.

Statistical analysis

Missing data were replaced using substitution of the mean [21], and outliers were removed before data analysis if data were two standard deviations away from the mean [22]. To determine if boxing improved muscle activity in persons with PD, a 2 × 2 repeated measures Analysis of Variance (ANOVA) was completed. The within factor was pre-and post-tests and the between factor was the Most Affected Side (MAS) and the Least Affected Side (LAS). To determine the contribution of aging to boxing, a 2 × 3 repeated measure ANOVA was completed. The within factor was pre-and post-tests and the between factor was group (PD, HOA, and HYA). The right side was entered for analyses, and thus only right-handed participants were included in the analysis.

Separate analyses were completed for the fast and self-paced conditions and the biceps brachii and triceps brachii. Post hoc comparisons were completed using Bonferroni Correction. Statistical tests were performed in SPSS and set at an alpha level of 0.05. Effect sizes were calculated using Cohen's d.

Results

EMG outcome measures for changes in muscle activity in people with PD

The mean and standard error for the fast conditions is shown in Figure 1. Results revealed a significant main effect of condition (pre to post boxing) for peak to offset time for the triceps brachii, only ($F(1)=5.869$; $p=0.046$; $d=0.205$). No differences in the condition were shown for any other outcome measures. There were no main effects for the side (MAS vs. LAS) and no interaction effects (Table 2).

The mean and standard error for the self-paced condition are shown in figure 1. Results revealed a significant main effect of condition for peak amplitude ($F(1)=7.079$; $p=0.045$; D=0.74 for MAS and d=1.09 for LAS) and for peak to offset time ($F(1)=7.512$; $p=0.029$, d=0.57 for MAS and d=0.54 for LAS) in the triceps brachii. No differences in condition were shown for any other outcome measures. There were no main effects for side and no interaction effects (Table 2).

EMG outcome measures for changes in muscle activity in people with PD compared to HOA and HYA

The mean and standard error for fast conditions is shown in figure 2. Statistical analysis revealed a significant main effect of condition for peak to offset time in the triceps brachii ($F(1)=8.181$, $p=0.009$; d=0.56 for PD, d=0.44 for HOA, and d=0.39 for HYA). There was no main effect of the condition on any other outcome measures. There were no main effects for the group and no interaction effects (Table 3).

The mean and standard error for self-paced right conditions is shown in figure 2. A significant main effect for condition was shown for peak amplitude in the triceps brachii ($F(1)=4.587$, $p=0.042$, d=0.94 for PD; d=0.47 for HOA, and d=0.30 for HYA) and peak to offset time in the biceps brachii ($F(1)=4.256$, $p=0.018$; d=0.71 for PD, d=0.19 for HOA, and d=0.001 for HYA). No main effect of the condition was shown for any other outcome measure. There were no main effects on the group. However, an interaction

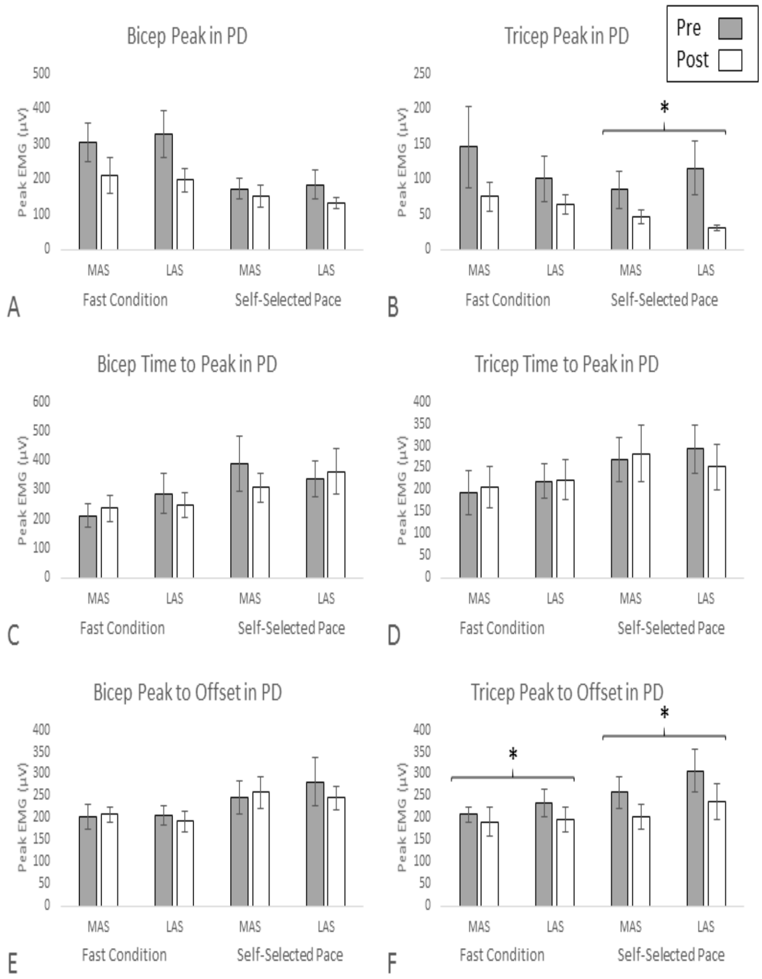

Figure 1. Mean values with standard error for Most Affected Side (MAS) pre-post compared to Least Affected Side (LAS) pre-post fast and self-paced conditions in people with Parkinson's Disease (PD) for the biceps brachii and the triceps brachii (*p-value < 0.05).

Table 2. Main effects of condition for PD.

Outcome Measure	Fast Condition					Self-paced Condition				
	Time		Side		Interaction	Time		Side		Interaction
	F	p	F	p	p	F	p	F	p	p
Peak Bicep	5.557	0.065	0.383	0.563	0.127	1.703	0.24	0.079	0.789	0.516
TTP Bicep	1.965	0.204	0.754	0.414	0.317	1.944	0.206	0.006	0.942	0.327
PTO Bicep	0.369	0.563	0.005	0.947	0.894	0.141	0.719	0.095	0.767	0.432
Peak Triceps	1.615	0.273	0.514	0.513	0.533	7.079	0.045*	0.163	0.703	0.992
TTP Triceps	0.827	0.393	0.584	0.47	0.756	0.827	0.393	0.584	0.47	0.756
PTO Triceps	5.869	0.046*	0.58	0.471	0.318	7.512	0.029	4.665	0.068	0.901

**p-value*<0.05, degrees of freedom for Time and Side: 1; PD: People with Parkinson's Disease, TTP. Time To Peak, PTO: Peak To Offset Time, Peak: Peak Amplitude

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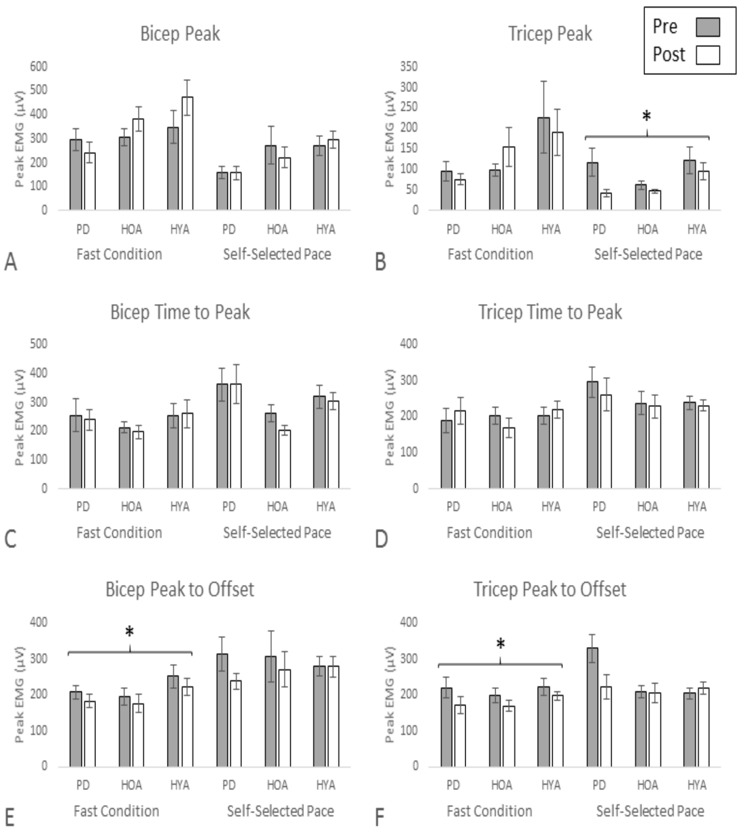

Figure 2. Mean values with standard error for fast and self-paced right conditions in people with Parkinson's Disease (PD), Healthy Older Adults (HOA), and Healthy Younger Adults (HYA) for the biceps brachii and the triceps brachii. (*p-value<0.05).

Table 3. Main effects of condition.

Outcome Measure	Fast Condition					Self-paced Condition				
	Time		Group		Interaction	Time		Group		Interaction
	F	p	F	p	p	F	p	F	p	p
Peak Bicep	0.123	0.729	1.156	0.243	0.864	0.494	0.488	1.667	0.209	0.433
TTP Bicep	1.468	0.239	0.462	0.636	0.633	1.843	0.187	2.13	0.14	0.257
PTO Bicep	2.7	0.115	0.049	0.952	0.9	4.256	0.018*	0.111	0.895	0.224
Peak Triceps	0.247	0.624	1.813	0.188	0.486	4.587	0.042*	1.099	0.349	0.452
TTP Triceps	0.094	0.726	0.176	0.839	0.067	0.64	0.431	0.048	0.953	0.616
PTO Triceps	8.181	0.009*	0.039	0.92	0.831	4.256	0.05	0.592	0.561	0.002*

*p-value < 0.05, degrees of freedom for Time and Group: 1, TTP. Time To Peak, PTO: Peak To Offset Time, Peak: peak amplitude

effect was shown for a peak to offset time in the triceps brachii (p=0.002). Post hoc analyses revealed no significant differences. No other interaction effects were shown (Table 3).

Discussion

This study is the first to examine the effects of an acute session of boxing on muscle activity in persons with PD. Results from this study showed the main effect of condition for the peak to offset time in the triceps brachii during fast movement and both peak amplitude and peak to offset time in the triceps brachii during self-paced movement. There were no differences between MAS and LAS after one session of boxing. Results also showed no statistical differences between people with PD, HOAs, and HYAs. Similar results to what was revealed for comparisons in persons with PD were revealed for all three groups. Results showed a main effect of condition for the peak to offset time in the triceps brachii during fast movement and both peak amplitude and peak to offset time in the triceps brachii during self-paced movement.

Results revealed statistical significance for the triceps brachii only for all three groups. A portion of the punching mechanics involved in boxing relies on triceps and biceps contraction. As the punch is thrown the triceps contract to extend the arm, and the biceps contract to counter hyperextension at the elbow joint. As the punch is being retracted, the biceps contract and contribute to elbow flexion to return the hand to the head as a defensive mechanism. Often in the sport of boxing, there is a greater emphasis on the movement of the punch being thrown out as opposed to being drawn back to its original position. This could explain why the main effects were seen primarily in the triceps.

Specific changes in the triceps brachii included a decrease in peak amplitude and a decrease in peak to offset time. A decrease in peak amplitude after a session of boxing could be indicative of increased efficiency with use, as peak amplitude is typically higher with a larger amount of force generation required to complete a movement. Given the data, the collection task was elbow flexion and extension with no resistance, a decrease in peak amplitude may suggest that less force was required to perform the movement after the boxing session. Our results also showed a significant decrease in peak to offset time. This may also suggest increased efficiency or better recovery time (i.e. the relaxation of a muscle after contraction) after a session of boxing. Moreover, these same patterns of significance were seen in both HOA and HYA groups, suggesting that changes in muscle activity after boxing are not due to aging or disease.

While the changes in muscle activity were the same across groups, there were no differences between groups. Previous research has shown that people with PD had an increased number of EMG bursts, smaller burst amplitudes, and longer burst durations during wrist and elbow flexion compared to HOAs [23,24]. Population bias in this study may contribute to the lack of differences. People with PD recruited for this study were high functioning, did not use assisted devices, were in the early stages of the disease, and actively participated in other weekly exercise groups. Thus, participation in the boxing outreach group before the acute intervention or the lack of disease may explain similarities between groups. Data were collected while participants with PD were on medication, which may also contribute to a lack of significance. Indeed, previous research has shown that medication affects EMG activity in the upper extremity [23,24]. Moreover, the HOA group was also highly active and attended an exercise program three times a week targeting muscular strength and cardiovascular endurance. This may explain the lack of difference between this group and the HYA group. Future research should consider the inclusion of participants with more diversity in disease and physical function.

There was a lack of statistically significant findings in many EMG outcome measures across all groups. This is in contrast to previous research in power and strength-based programs. Studies in older adults have shown increases in EMG activity, peak force, and rate of force development [25-28]. However, these studies included resistance training over a longer period (two to four months). The boxing program implemented in this study focused solely on one session of high-velocity movements with little to no resistance. A lack of a stressor to induce progressive neuromuscular adaptation over time may explain the lack of differences in the other outcome measures in this study. Future research should consider long-term changes in muscle activity after boxing in people with PD.

Limitations

Previous research has shown that fatigue impacts muscle activity [29]. No report of fatigue was collected during this study; thus, fatigue may have contributed to the findings. The tissue composition of the area where EMG electrodes were placed, especially the triceps brachii, contains greater levels of fat mass in older adults. This may have affected surface electrode conductance during data collection. Nonetheless, significant results were revealed for the triceps brachii. Finally, fast repetitive movements may have increased noise in the EMG signal. However, EMG data was inspected for artifacts, and outliers were removed.

Conclusion

Results from this study suggest that an acute session of boxing may improve muscle activity in the triceps brachii in people with PD. Moreover, these changes are likely not due to aging or disease. This is the first study, to our knowledge, to examine the effects of boxing on physiology, rather than behavior alone, and contributes to the body of evidence supporting boxing as a potential alternative therapeutic tool for people with PD. Results from this study provide a basis for continued research to determine the efficacy of boxing in people with PD, especially considering long-term training programs, functional outcomes, and a more diverse PD population.

Declaration

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Notes

This study was conducted in partial fulfillment of the requirements for the first author's Master of Science degree. That thesis can be found in the following citation.

Meyer O. Effects of boxing on force characteristics in the upper extremities in people with Parkinson's disease compared to healthy younger and healthy older adults [master's thesis]. Ames (IA): Iowa State University; 2019.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

References

1. Marras, C., et al. "Prevalence of Parkinson's disease across North America". *NPJ Park's Dis***.** 4.1(2018):1-7.
2. Tysnes, O.B and Storstein, A. "Epidemiology of Parkinson's disease". *J NeuralTransm*. 124.8(2017):901-905.
3. Keus, S.H, et al. "Evidencebased analysis of physical therapy in Parkinson's disease with recommendations for practice and research". *Mov Disord*. 22.4(2007):451-460.
4. Miyai, I., et al. "Treadmill training with body weight support: its effect on Parkinson's disease". Arch Phys. Med Rehabil. 81.7(2000):849-852.
5. Miyai, I., et al. "Long-term effect of body weight–supported treadmill training in Parkinson's disease: A randomized controlled trial". *Arch Phys. Med Rehabil* .1083(2002):1370-1373.
6. Herman. T., et al. "Six weeks of intensive treadmill training improves gait and quality of life in patients with Parkinson's disease: a pilot study". *Arch Phys. Med Rehabil*. ;88.9(2007):1154-1158.
7. Hackney, M.E, and Earhart, G.M. "Tai Chi improves balance and mobility in people with Parkinson disease". *Gait & posture*. 2008;28.3(2008):456-460.
8. Li, F., et al. "Tai chi and postural stability in patients with Parkinson's disease". New England Journal of Medicine. 2012 Feb 9;366(6):511-519.
9. Gao,Q., et al. "Effects of Tai Chi on balance and fall prevention in Parkinson's disease: a randomized controlled trial". *Clin Rehabil*. 28.8(2014):748-753.
10. Nieuwboer, A., et al. "Cueing training in the home improves gait-related mobility in Parkinson's disease: the RESCUE trial". *J Neurol Neurosurg Psychiatry*. 78.2(2007):134-140.
11. Thaut, M.H., " Rhythmic auditory stimulation in gait training for Parkinson's disease patients". *Mov Disord*. 11.2(1996):193-200.
12. Protas, E.J et al " Gait and step training to reduce falls in Parkinson's disease". *Neuro Rehabil*. 20.3(2005):183-190.
13. Alberts ,J.L, et al. "Cortical and motor responses to acute forced exercise in Parkinson's disease". *Park Relat Disord*. 24(2016):56-62.
14. King, L.A, and Horak ,F.B. " Delaying mobility disability in people with Parkinson disease using a sensorimotor agility exercise program". Phys Ther. 89.4(2009):384-393.
15. Combs, S.A. "Boxing training for patients with Parkinson disease: a case series". *Phys Ther*.91.1(2011):132-142.
16. Combs, S.A., et al "Community-based group exercise for persons with Parkinson disease: a randomized controlled trial". *NeuroRehabilitatio*; 32.1(2013):117-124.
17. Borrero, L., et al."The meaning of regular participation in vigorous-intensity exercise among men with Parkinson's disease" . *Disabil Rehabil*.23 (2020):1-7.
18. Horbinski, C., et al " Longitudinal observational study of boxing therapy in Parkinson's disease, including adverse impacts of the COVID-19 lockdown". *BMC neurol*. 21.1(2021):1-0.
19. Clarke, C.E., et al. "Clinical effectiveness and cost-effectiveness of physiotherapy and occupational therapy versus no therapy in mild to moderate Parkinson's disease: a large pragmatic randomised controlled tria (PD REHAB)"23.63(2016).
20. Folstein, M.F, et al. "Mini-mental state: a practical method for grading the cognitive state of patients for the clinician". J Psychiatr Res.;12.3(1975):189-198.
21. Roth, P.L, Switzer, III. FS and Switzer, D.M. "Missing data in multiple item scales: A Monte Carlo analysis of missing data techniques" *Organ Res Methods*. 2.3(1999):211-232.
22. Van, Selst. M, and Jolicoeur, P. "A solution to the effect of sample size on outlier elimination". J Exp Psychol;47.3(1994):631-650.
23. Berardelli, A., et al. "Scaling of the size of the first agonist EMG burst during rapid wrist movements in patients with Parkinson's disease". *J Neurol Neurosurg Psychiatry*. 49.11(1986):1273-1279.
24. Benecke. R., et al. "Simple and complex movements off and on treatment in patients with Parkinson's disease". *J Neurol Neurosurg Psychiatry*. 50.3(1987):296-303.
25. Häkkinen, K., "Changes in electromyographic activity, muscle fibre and force production characteristics during heavy resistance/power strength training in middleaged and older men and women". *Acta*

Physiol Scand.171.1(2001):51-62.

26. Kyröläinen, H., et al. "Effects of power training on muscle structure and neuromuscular performance". *Scand J Med Sci Sports*. 15.1(2005):58-64.
27. Caserotti, P., et al. "Explosive heavyresistance training in old and very old adults: changes in rapid muscle force, strength and power". *Scandj Med Sci Sports*. 18.6(2008):773-782.
28. Wallerstein , L.F., et al "Effects of strength and power training on neuromuscular variables in older adults." *J Aging Phys Act*.20.2(2012):171-185.
29. Dimitrova, N.A and Dimitrov. G.V. "Interpretation of EMG changes with fatigue: facts, pitfalls, and fallacies". *J Electromyogr Kinesiol*.;13.1(2003):13-36.

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